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An Empirical Approach for Relating Annual TSP Concentrations to Particulate Microinventory Emissions Data and Monitor Siting Characteristics

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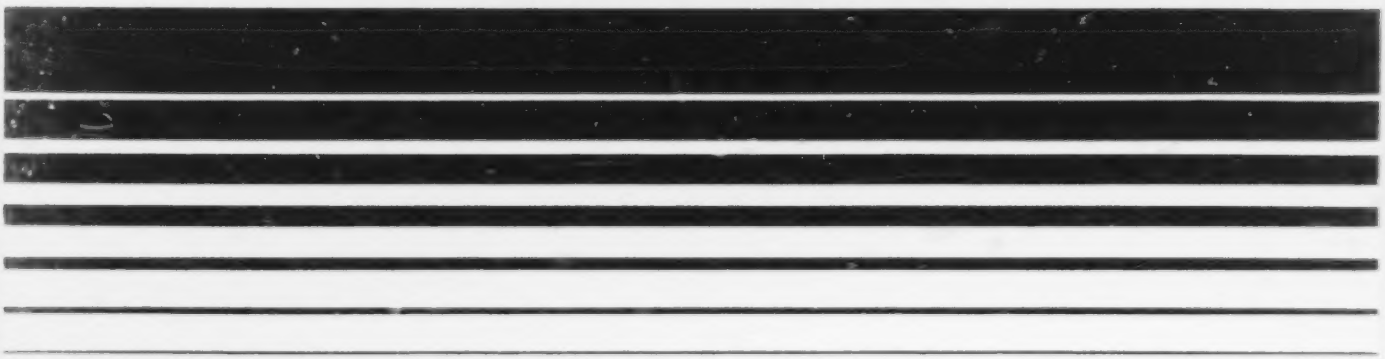

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16. ABSTRACT

Procedures for developing and applying an empirical procedure for relating microinventory data to annual TSP data is described herein. A microinventory is an inventory and orderly compilation of sources in the vicinity of a high volume sampler. Its purpose is to consolidate information on source emissions or activity rates, monitor siting, air quality data and land use characteristics into a consistent format and data base. The purpose of the microinventory is to assist in identifying the sources of particulate matter in close proximity to a monitoring site. Such information can subsequently be used to interpret observed differences in air quality at various monitoring sites.

An empirical approach in which monitor siting characteristics and microinventory information are related to measured annual mean TSP concentrations using multiple regression analysis has been developed. The regression uses variables which consider the emissions and distances to both point and area sources and the effects of traffic and dust on nearby streets upon measured TSP concentrations. The purpose of this report is to describe: 1) the methodology used in compilation of a microinventory and 2) the development of uses of an empirical approach for relating observed annual TSP levels to microinventory and monitor siting information.

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Prepared for

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INTRODUCTION

A recent nationwide study of Total Suspended Particulate (TSP) indicated that an average of around one-third of the TSP found on the high-volume sampler comes from industrial types of sources.[1] Another one-third of the TSP is attributed to background or distant natural and man-made sources, while the remaining one-third is due to nontraditional sources such as fugitive dust and area source combustion products. This study suggested that these nontraditional sources have their greatest impact in their immediate vicinity while industrial process sources seem to have their greatest influence over a broader scale of several miles because of their higher effective stack height. Several other studies noted similar findings.[2,3] In the past, emission inventories have frequently been compiled for use in atmospheric dispersion models to assess the impact of various source categories and control strategies for these sources. Spatial resolution of these inventories has typically been limited to 1 or 2 km square grids, even in the most densely populated or industrialized areas. Also, many of the source categories are allocated to these grids by population or other demographic indicators. Such allocations do not necessarily reflect a true emissions profile of the area immediately surrounding each monitor. One modeling effort apportioning vehicle related particulate emissions from major paved roads into 1 km grids, greatly improving the model's predictive capability.[4] In another study, the effect of the particulate emissions associated with a given roadway was shown to diminish rapidly as the distance away from a roadway increased, indicating the importance of improving our knowlege of sources within several hundred feet of a monitoring site.[5] Several studies have attempted to describe the area around monitoring sites in detail using pictures, sketches, scaled maps, site descriptions and/or emission inventories.[1,2,3,6,7]

Procedures for developing and applying a microinventory are described herein. A microinventory is an inventory and orderly compilation of sources in the vicinity of a high volume sampler. Its purpose is to consolidate information on source emissions or activity rates, monitor siting, air quality data and land use characteristics into a consistent format and data base. The purpose of the microinventory is to assist in identifying the sources of particulate matter in close proximity to a monitoring site. Such information can subsequently be used to interpret observed differences in air quality at various monitoring sites. Emissions from point sources within five miles and area source emissions within one mile are inventoried. Documentation of these emissions becomes most precise in the area closest to the monitor. Monitor siting characteristics such as height and distance from sources within 200 feet are recorded as a part of the microinventory.

An empirical approach in which monitor siting characteristics and microinventory information are related to measured annual mean TSP concentrations using multiple regression analysis has been developed. The regression uses variables which consider the emissions and distances to both point and area sources and the effects of traffic and dust on nearby streets upon measured TSP concentrations. The purpose of this report is to describe: 1) the methodology used in compilation of a microinventory and 2) the development and uses of an empirical approach for relating observed annual TSP levels to microinventory and monitor siting information.

MICROINVENTORY METHODOLOGY

The term "microinventory" has been used to describe the procedure of estimating annual particulate emissions in the area surrounding hi-volume sampler sites.[8] The methodology for the procedure has evolved from a fairly simple genesis into a detailed compilation of sources and their distances and directions from monitors.[9]

A microinventory must be conducted over a geographical area large enough to include the location of most of the sources believed or assumed to have significant effect on TSP air quality. This geographic area will necessarily be different for elevated point sources than the ground level or rooftop emission height of area sources because of the greater dispersion potential for emissions from the taller stacks characteristic of the major point sources.

The distances suggested for a microinventory are five miles radius for point sources and one mile radius for area sources. The following rules of thumb are suggested for point sources: a) all sources within one mile radius be included, b) from one to three miles distance, only those sources greater than or equal to 100 tons per year actual emissions be included and c) from three to five miles distance, only those sources greater than or equal to 250 tons per year be included in the microinventory. These rules of thumb were selected after review of Gaussian dispersion model applications and theory to include the significant sources impacting air quality. Point sources are further described in the microinventory as to their distance and direction from the monitor. This information provides additional perspective on the sources and their potential for influencing TSP concentrations.

For area sources, the large number of small sources, diversity of source shapes and broad land area coverage would make such a listing impractical if not impossible. Considering the practical constraints, an inventory technique has been developed which places the area sources into annular sectors in four directions and three distances from the monitor as depicted in Figure 1. (Figure 2 suggests a grid system for use with dispersion models which require Cartesian coordinate systems). Within the center section (Sector 1), the major sources within 200 feet of the monitor are described as to their distance and direction from the monitor. Sources within the quarter-mile radius (Sector 1) are considered to be sufficiently close to the site that they would affect the monitor under most wind conditions and thus, no compass directions were recorded. Separate tabulations are made for area sources within each of the nine sectors. An example of an area source inventory around a TSP site is given in Table 1. Also, Figure 3 is a sketch of the quarter-mile area around the monitor.

Fugitive dust sources are generally the dominant area sources. These include dust from paved roads, unpaved roads and parking lots, cleared areas, construction, rail yards, agricultural tilling, etc. Industrial processes smaller than the point source cutoff of 25 tons per year actual emissions can also be listed. Also included are area combustion sources such as space heating, small boilers and incinerators which were not included in the point source inventory, and vehicle exhaust. A gridded inventory using demographic allocation methods is generally used for stationary combustion sources, and these are apportioned into the nine sectors by land area.

Figure 1. Standard sectors used in Microinventory Analysis for Area Sources

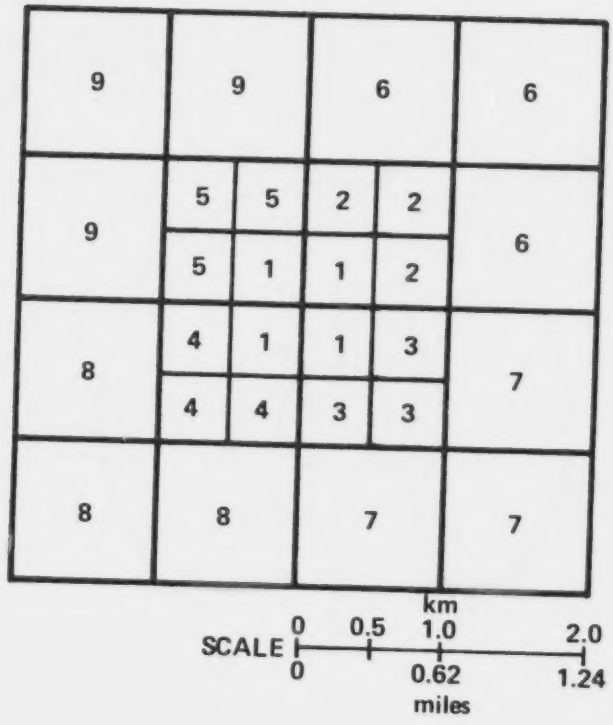


Figure 2. Microinventory grid system recommended for use with dispersion models

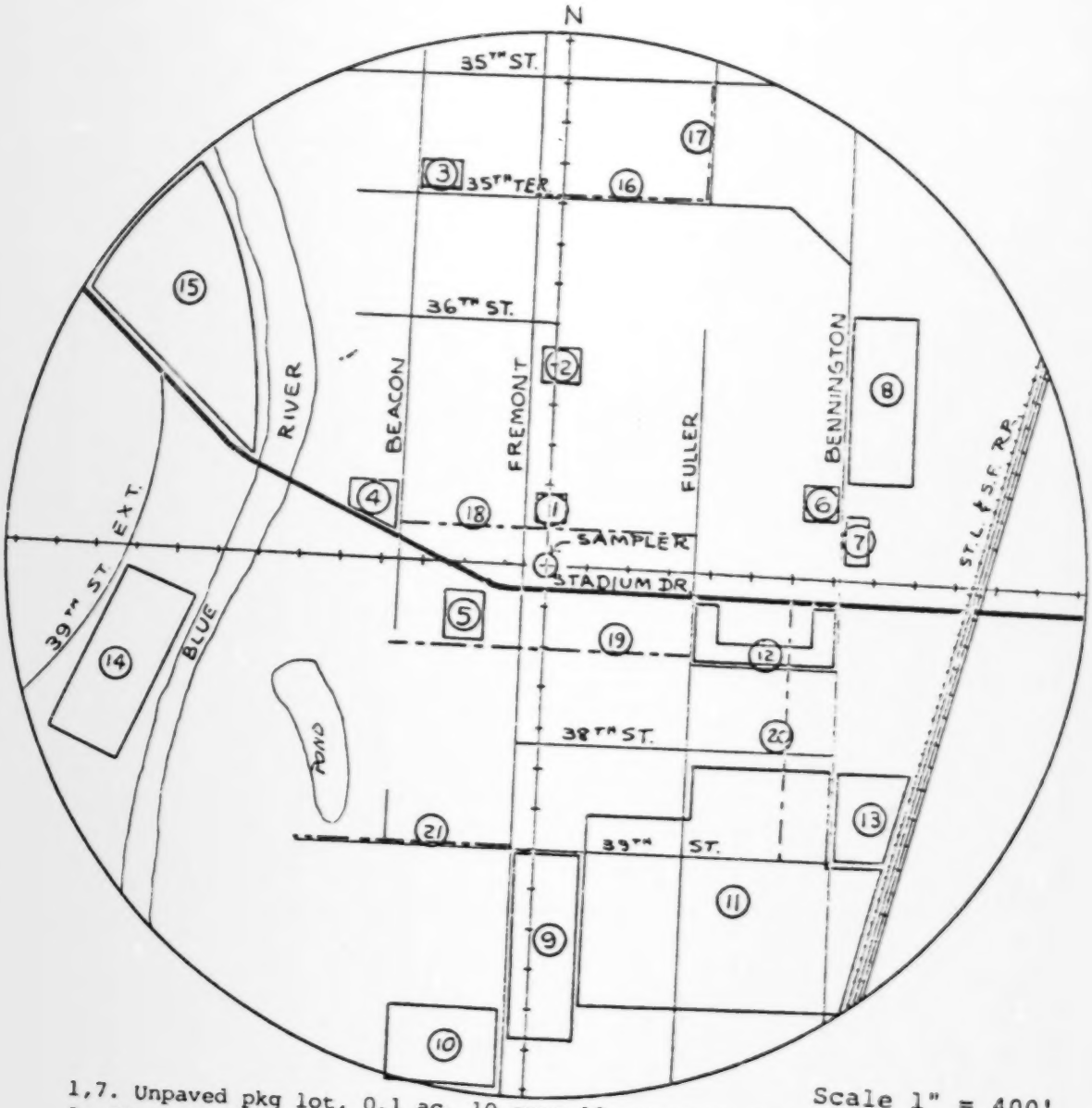
TABLE 1. Example of Area Source Invenventory Around TSP Monitoring Sites.

AREA SOURCE SUMMARY

Site: 6402 East 37th

Source category	Activity rate	Emissions by sector, ton/yr									
		1	2	3	4	5	6	7	8	9	Total
COMBUSTION:											
Residential fuel	9491 pop	0.2	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.5	2.6
Comm/Ind fuel	8081 emp	0.5	0.4	0.4	0.4	0.4	1.5	1.5	1.5	1.5	8.1
Incinerators											
Rail/Air											
Auto exhaust	97.4×10^6 VMT	1.9	0.6	0.6	0.2	0.6	27.0	16.7	3.2	13.5	64.3
INDUS PROCESSES:											
Ind processes	4 sources	1		10					1.6	1.0	13.6
FUGITIVE DUST:											
Railroad yards	78 ac	0.4	2.0	1.2			3.0	0.5	0.7		7.8
paved streets	94.5×10^6 VMT	10.6	3.6	3.6	1.4	3.6	152.3	95.6	14.1	70.8	355.6
Unpaved roads	2.7×10^4 VMT	1.2									1.2
Cleared areas	0.1 ac	neg									
Construction											
Agriculture											
Storage areas	16 ac	3.2									3.2
Unpaved pkg lots	25.4 ac	4.8					12.0		7.4		24.2

Recap	Emissions by sector, t/yr			
	1	2-5	6-9	Total
COMBUSTION	2.6	4.0	68.4	75.0
IND PROCESSES	1.0	10.0	2.6	13.6
FUGITIVE DUST	21.8	15.4	404.2	441.4
Total	25.4	29.4	475.2	530.0



Scale 1" = 400'

1,7. Unpaved pkg lot, 0.1 ac, 10 cars
2. Cleared area, 0.1 ac
3,6. Unpaved pkg lot, 0.1 ac, 5 cars
4. Unpaved storage area, 0.2 ac
5. Unpaved pkg lot, 0.3 ac, 25 cars
8. Unpaved pkg lot, 1.7 ac, 35 trucks
9. Unpaved pkg lot, 1.5 ac, 150 cars
10. Unpaved storage area, 2.0 ac
11. Unpaved storage area, 8.1 ac
12. Unpaved pkg lot, 0.8 ac, 20 cars
13. Unpaved pkg lot, 0.7 ac, 50 cars
14. Unpaved storage area, 3.4 ac
15. Unpaved storage area, 2.3 ac
16. Unpaved road, 400 ft, 5 cars
17. Unpaved road, 300 ft, 10 cars
18,19. Unpaved alley, 750 ft, 5 cars
20. Unpaved road, 675 ft, 5 cars
21. Unpaved road, 600 ft, 5 cars

One-quarter mile radius around 6402 East 37th site.

Figure 3. Sketch of the one-quarter mile radius around an example site.

The emission factors used in the inventory should be consistent with published EPA factors.[10] The factors or formulas used to estimate fugitive dust emissions in a recent microinventory of sites in Kansas City, along with a summary of these calculations is given in Appendix A. These emission factors were applied to activity factors such as VMT (vehicle miles traveled), acres of tilled land, etc., to compute the emission estimates for each sector. A description of the procedure recommended for use in deriving the information needed to compile a microinventory follows. The procedure consists of two steps: 1) a preliminary survey, and 2) a final survey and computations.

PRELIMINARY SURVEY

The procedure for determining the locations of the sources and their activity levels should be carefully developed to minimize time required in the field. A preliminary survey is suggested if the sites to be inventoried are not located in the same area as the agency or person performing the inventory. This is a one-to two-day visit to the sites to be inventoried. Table 2 indicates the information obtained during the preliminary survey.

FINAL SURVEY AND COMPUTATIONS

Following this preliminary survey, a grid of the road network within Sector 1 is drawn to scale using a map such as the U.S. Geological Survey 7 1/2 minute quadrangle. Then the distances and directions from the sites to the point sources are calculated. Aerial photos can be used as one means of locating cleared areas or other fugitive dust sources, or alternatively, a visual drive through can be made. The final survey visit consists of a detailed visual inspection of the vicinity of the site. The condition of the

TABLE 2. Information to be Obtained in Preliminary Survey

- U.S. Geological Survey Maps of the Area
  (from a local engineering supply store in most areas)
- Land Use Maps
  (from local Council of Governments - COG)
- Traffic Data
  (from local COG, or city or State transportation agency)
- TSP Annual Air Quality Data and Site UTM Coordinates
  (State/local Air Pollution Agency)
- Gridded Inventory of Area Combustion Sources
  (State/local Air Pollution Agency)
- Point Source Inventory Including Annual TSP Emissions over 25 TPY and UTM coordinates
  (State/local Air Pollution Agency)
- Precise Location of Hi-vol Including Height and Distance to all Major Sources (such as roads, parking lots, etc., within 60 meters)
  (obtained during site tour)
- Photographs of Site and Surrounding Area
  (obtained during site tour)
- Aerial Photographs (optional)
  (usually available through COG)

streets (e.g., presence of paving, curbs, etc.) is described. The location and activity level of unpaved or gravel parking, for example, is estimated by the best available means (talk with owner or attendant, or estimate lot capacity and turnover rate). The locations of very close point sources (as calculated from UTM coordinates) are confirmed. The mile radius area is checked for omissions from the point source inventory. Any obviously unusual characteristics that may not have been considered accurately in the area source allocation scheme (such as a concentration of coal-or wood-fired space heaters and fireplaces) are noted, and appropriate adjustments should be made to the inventory. The final survey usually requires two persons for about one-third to one-half day in the field per site, depending upon the complexity of the area and the number of fugitive sources. All of this information is then used to estimate an annual emission inventory for each of the sectors in Figure 1.

Predominant land use in each sector and in the several mile area surrounding the inventory area can be estimated by visual inspection or, if warranted, through land use maps. For further accuracy, the 1/4 mile radius sector (Sector 1) can be divided into quadrants and these classified according to land use. Such information may be useful for future planning and projection activities. Table 3 indicates the land use categories and classification criteria which were found to be useful.

An example microinventory for a site in Kansas City, Missouri, is in Appendix B. It includes a site description, area source inventory, one mile map, quarter-mile sketch, and photographs. Appendix C suggests uses for the microinventory which are not directly related to the empirical technique which will be discussed next.

TABLE 3. Land Use Categories and Classification Criteria

CATEGORIES	CRITERIA
Undeveloped	No significant activity; includes parks and pasture land
Agriculture	Active farming
Light residential	Four or less dwelling units/acre
Dense residential	Greater than four dwelling units/acre
Suburban commercial	Retail businesses in strip development or shopping centers
Central commercial	Central business district
Light industry	Metal fabrication, warehousing, trucking, etc.
General industry	Controlled industrial processes
Heavy industry	Steel mills, foundries, coking, etc.
Airport	Municipal airport

DEVELOPMENT OF THE EMPIRICAL TECHNIQUE

This technique represents an approach to quantifying the relationship between particulate emissions, monitor siting characteristics, and annual ambient measurements of Total Suspended Particulates (TSP) using a micro-inventory data base. It requires a moderately intensive data gathering effort to quantify the emissions and environment in the immediate vicinity (i.e., up to five miles) of high volume sampler sites.

The empirical method is a regression equation which relates monitoring site characteristics and microinventory information to observed annual mean TSP concentration. The data base used in the development of the method included data for 79 sites in four urban areas (Portland, Oregon, Bimingham, Alabama, and the St. Louis and Kansas City metropolitan areas).[11,12,13,14]

FORM OF THE METHOD

The form of the method is a multiple linear regression equation with annual geometric mean TSP concentration as the dependent variable and four independent variable terms. The independent variables are: 1) AREA, annual area source particulate emissions within one mile (including fugitive dust and influence of monitor height); 2) POINT, annual point source emissions within five miles; 3) LOCAL, local sources (those traffic-related sources within 200 feet) and 4) VISPLUME, an indicator variable for the presence of a visible plume of resuspended dust resulting from passing traffic on the nearest streets (within 200 feet). In addition, the differences in concentrations among urban areas due to areawide factors (e.g., natural and transported background) not included in the microinventory were estimated by assigning a "city effects"

classification variable to each urban area. These are also independent variables in the equation. These variables were selected after examining the correlation matrix for approximately 30 potential variables, as listed in Appendix D.

As can be seen from the appendix, many different data transformations involving height of the monitor, distance of the sources, etc., were attempted. The final selection of variables was based on the degree of intercorrelation between each of these variables and average ambient air quality. Partial correlation coefficients were developed, holding the effects of other variables constant, and those selected gave the highest partial correlations to average air quality. Also, consideration was given to the interdependence among the independent variables in arriving at the final selection. For instance, it may have been desirable to consider individual categories of area source emissions, such as paved roads, unpaved roads, and others separately. However, the relatively high intercorrelation between such variables necessitated the exclusion of one of these variables from the regression model. Multiple regression was then employed to derive the coefficients for each of the terms in the equation and to obtain the statistical values used to judge the accuracy of the regression equation.[15]

The multiple correlation coefficient, (r), with the four variables and city effects constants, K_i, in the regression equation was 0.876 using all 79 data sets; none were eliminated as outliers. Therefore, the seven variables explained 77 percent of the variance (r^2) in measured concentrations.

The regression equation is given by:

$$\text{AVGAQ} = 0.00451\ (\text{AREA}) + 0.00096\ (\text{POINT}) + 50.5\ (\text{LOCAL}) + 18.6\ (\text{VISPLUME}) + K_i\ (\text{"city effects" variables}) \quad (1)$$

where AVGAQ = Predicted annual geometric mean, $\mu g/m^3$

$$\text{AREA} = \frac{A_1}{0.0324}\,\frac{25}{\text{HGT}} + \frac{A_2+A_3+A_4+A_5}{0.16} + \frac{A_6+A_7+A_8+A_9}{0.6084}$$

The constants .0324, .16 and .6084 are the square of the radius in miles to the area weighted center of the annular ring defined by the sectors in the numerator.

A_i = Total area source emissions in sector i, ton/yr (sector locations are shown in Figure 1)

HGT = Height of sampler, ft

$$\text{POINT} = \sum_{i=1}^{n} \frac{\text{PSEM}_i}{D_i^2}\ (\text{WWF})$$

n = Number of point sources within 5 miles

PSEM_i = Emissions from point source i, ton/yr

D_i = Distance to point source i, mile (lower limit of D_i is 0.5)

WWF = Wind weighting factor, computed as annual wind direction frequency of occurrence (%) in quadrant where source is located, divided by 25, dimensionless

$$\text{LOCAL} = \frac{\ln \text{ADT}_1}{\sqrt{\text{HGT}^2+\text{DIS}_1^2}} + \frac{\ln \text{ADT}_2}{\sqrt{\text{HGT}^2+\text{DIS}_2^2}}$$

ADT_i = Average daily traffic on nearby road i, veh/day

DIS_i = Distance to road i, ft (upper limit of DIS_i is 200)

VISPLUME = 0 if no visible plume of resuspended dust results from passing traffic on paved roads, 1 if there is a plume. the Care should be taken to assure that the conditions on street are typical of year-round conditions and not a short term dust loading, for example.

K_i (CITY EFFECTS)= Classification variables to account for different background concentrations in each of the cities. The "city effects" for each city were found to be:

Portland, 35.6 $\mu g/m^3$
St. Louis, 50.6 $\mu g/m^3$
Kansas City, 57.2 $\mu g/m^3$
Birmingham, 50.3 $\mu g/m^3$

The predicted versus observed concentrations are plotted from equation 1 in Figure 4.

Regression equations can be developed from the data sets in any one city and their use will be discussed later. For example, the equation derived with just the 32 Kansas City sites would be:

$$\begin{aligned} AVGKC = {} & 0.0054(AREA) + 0.00057(POINT) + \\ & 55.2(LOCAL) + 10.6(VISPLUME) + 57.6 \end{aligned} \qquad (2)$$

Similar equations were not calculated for the other cities because they had too few sites.

EVALUATION OF METHOD

Three separate evaluations of the regression model (Equation 1) were performed: 1) by using the statistics provided by the multiple regression program; 2) by testing stability of the coefficients in the equation; and 3) by testing the method's predictions with a new data set of emissions and air quality data collected at 28 sites in three other areas (Philadelphia, Pittsburgh and New England).

The summary statistics from the multiple regression analysis with 79 site data set are presented in Table 4. The correlation matrix revealed no significant intercorrelations between any of the independent variables used in the

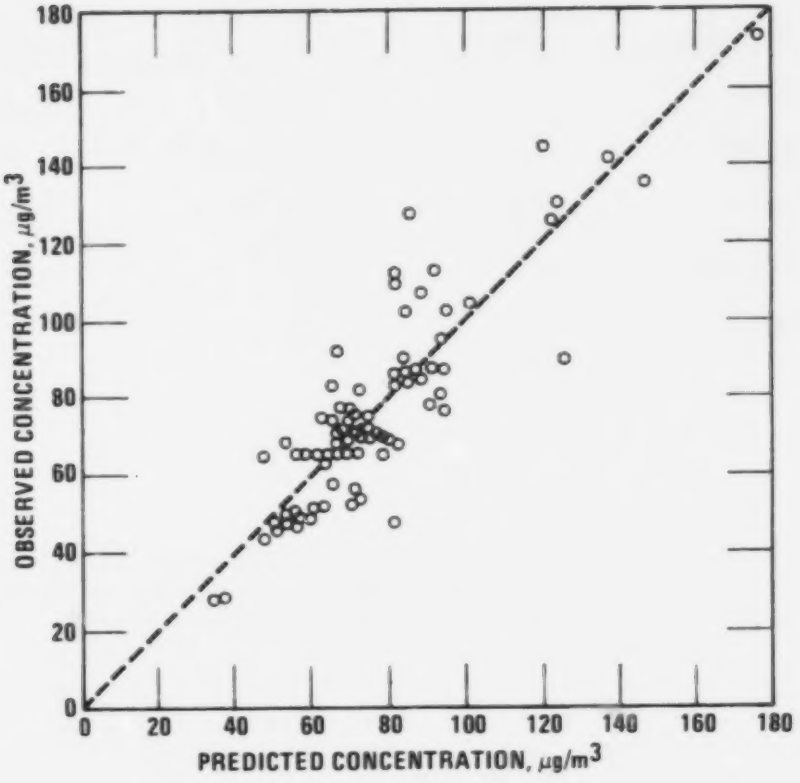


Figure 4. Plot of predicted versus observed concentration for regression

TABLE 4. SUMMARY OF MULTIPLE REGRESSION ANALYSIS

Variable	Regression Coefficient	Std Error of Regression Coefficient	Computed F Value
AREA	0.00451	0.00082	30.4
POINT	0.00096	0.00014	45.7
LOCAL	50.5	12.0	17.6
VISPLUME	18.6	4.9	14.6
Constant	*		

* The constant can be thought of as the value of the "city effects" variable. For instance, for a site in Portland, the intercept could be thought of as 35.6 $\mu g/m^3$.

regression. The t-test was used in testing the regression coefficient for each of the independent variables to determine whether each was significant. For the four variables and city effects constants and the 79 observations, F values in Table 4 indicate that all the coefficients are highly significant.[16]

The standard errors for the coefficients of the variables AREA, POINT, LOCAL and VISPLUME were only about 20 percent of the coefficient values. The standard error of the regression equation was 13.6 $\mu g/m^3$, about 17 percent of the average measured concentration. The relative errors for all but three of the 79 predicted concentrations were less than 28 percent. It should be emphasized again that none of the observations from the four cities were removed before performing the regression analysis, although some were suspected to contain anomalies. It was felt that these "anomalies" may represent "real" but unusual situations which might be encountered by users of this model.

The stability or sensitivity of coefficients in the equation was tested by running two additional regression analyses, each with 75 percent of the sites (selected at random) from the initial analysis. This was done to assure that there were not a small number of sites which might be responsible for determining the value of the coefficients. The AREA and POINT coefficients were found to be very stable, the LOCAL coefficient fairly stable, and the VISPLUME coefficient fairly sensitive to the specific sites included in the analysis. It was shown that excluding just a few influential sites from the regression could affect the VISPLUME coefficient by as much as 15 percent. However, VISPLUME was judged sufficiently stable and important to remain included in the regression equation.

In an effort to independently test the fundamental relationships in the empirical method, microinventories were obtained in Philadelphia, Pittsburgh and several sites in the New England area. These microinventories were then used to calculate values for the variables AREA, POINT, LOCAL and VISPLUME at each site. The product of the variable values and the variable coefficients for each variable were added together to give a "predicted" concentration at each site. These "predictions" for the sites in each area were compared with average annual mean concentrations at the sites to give an indication of the extent to which the regression explained the variance among the concentrations in each area.

Since equation 1 was developed empirically for four specific areas, it may not be appropriate to use it as a predictive model in other areas. This is because other factors, such as special terrain, or climate, may influence the absolute values of the concentrations it predicts. When applying the model to other areas, it is preferable to use it in a relative sense. This will be discussed later.

An example comparison of predicted and observed concentrations is given in Figure 5. In calculating the predicted concentrations in Figure 5, only the LOCAL, AREA, POINT and VISPLUME terms of equation 1 were used. Table 5 summarizes the correlation coefficients (between predicted and observed) and city effects constants (K) for each of the three test case areas. In Table 5, the city effects constants, K, were calculated as the average differences between (observed concentration - predicted concentration) at each site in the area.

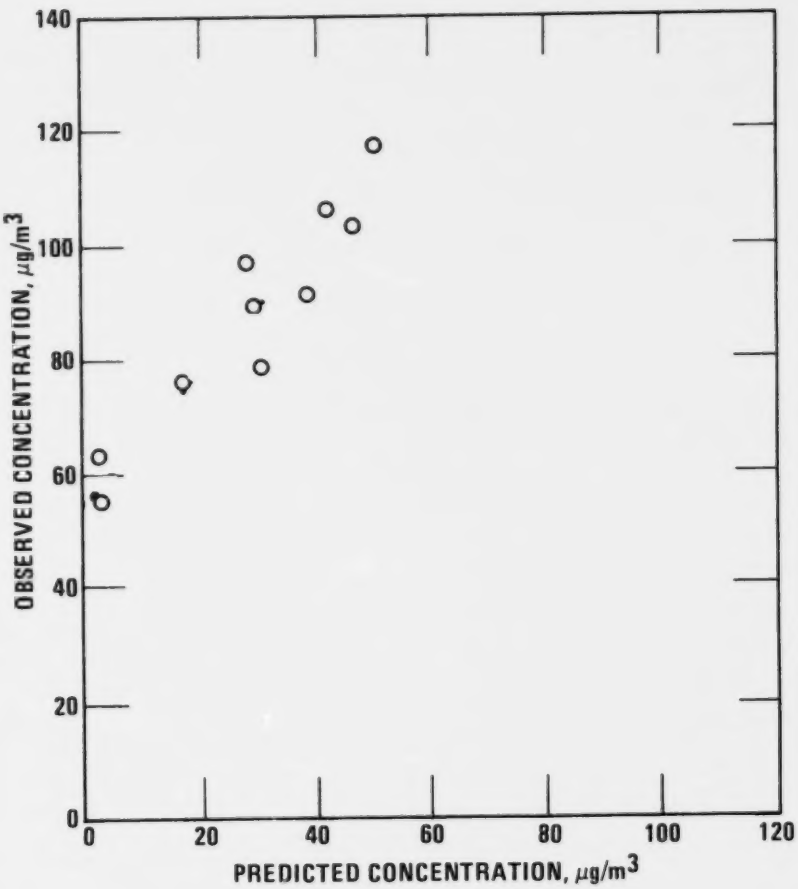


Figure 5. Plot of predicted versus observed concentration in Philadelphia Using LOCAL, AREA, POINT and VISPLUME terms in Equation 1

TABLE 5. COMPARISON OF PREDICTED AND OBSERVED CONCENTRATIONS IN THREE URBAN AREAS

City	No. of Sites	r	r^2[a]	K_i Average Difference between Predicted and Observed, $\mu g/m^3$
Philadelphia[b]	10	0.95	0.90	58
Pittsburgh[c]	7	.94	.88	70
New England[c,d]	11	.93	.86	34

[a] It represents the fraction of the variation in concentrations between sites, which is explained by the model.

[b] Reference 17

[c] Reference 18

[d] Reference 19

The "city effect" represents that portion of the concentration which is assumed to be relatively constant across the study area and is not accounted for by the AREA, POINT, LOCAL and VISPLUME terms of the equation. This portion is thought to have several distinguishable components. The largest component of K is probably background, the portion of ambient concentrations which cannot be reduced by controlling emissions from local manmade sources. Background in turn has many components, including windblown dust from natural surfaces, biological debris, and long-range transport of both primary and secondary aerosols. Background for an urban area is usually measured at a nonurban site near the urban area which is unaffected by nearby emission sources and represents the air which flows into an area.

Two other probable components of the constant value could be collectively described as "urban excess," in that these components would not be accounted for in a measured nonurban background concentration. The first of these is locally emitted sulfates, nitrates, and organics that form secondary aerosols in the atmosphere. Long-range transport would include additional secondary aerosols that would be included in the background value described above. The other component would be the collective impact of area and small point sources located in the urban area but outside the one mile radius microinventory area.

Since the impacts of the above sources vary considerably from city to city but to a much smaller degree for different sites within the same urban area, the constant should also vary depending on the city. The method for determining this city-specific correction to equation 1 is discussed further in the report which describes the validation of this empirical technique.[12]

POTENTIAL APPLICATIONS AND EXAMPLES

There are two applications of the regression study which will be discussed in more detail. These include the predictions of source impacts from the calculation of city-specific regressions (e.g., Equation 2) and the calculation of relative source impacts from Equation 1.

Calculation of a City-Specific Regression (Equation 2)

The most desirable way to apply the above analysis is to estimate the regression equation coefficients for a specific city using the four regression variables (LOCAL, POINT, AREA, VISPLUME) and data for sites in that city. To do this, one would calculate values for each of the four variables using the microinventory collected at a number of sites in an urban airshed. Then a multiple regression would be performed to estimate the regression coefficients for the specific city involved. No firm guidance can be given on how few or how many sites are necessary to perform such a regression because the variability of the data and representativeness of the sites will be different in different situations. It may be possible to perform the regression using as few as 12 or 15 sites, if there is good agreement in the data and if the regression coefficients appear stable. Such a decision (on the number of sites required) will require inspection and evaluation of the preliminary regression runs and standard statistical texts should be consulted. If such a regression were performed, the equation could be used as a predictive model within the range of the observations.

An example of a city-specific regression was given in Equation 2 for data in Kansas City. The coefficients of the other variables are slightly different from those in Equation 1, indicating that some factors influencing the source-receptor relationship in Kansas City may be slightly different from the "average"

conditions in the four cities used to develop equation 1. Several factors could effect the values of city-specific regression coefficients, the most likely being dispersion meteorology. Other factors might be the presence or absence of major point source (or fugitive dust) oriented sites or just random differences in the most probable values, exacerbated by the smaller size of the data set.

Calculation of Relative Source Impacts from Equation 1

Unfortunately, it may not always be possible to calculate a city-specific regression equation. In these cases, it would be desirable to use Equation 1 in some manner to assist in the analysis of the TSP problem in that area. Therefore, it is suggested that the variables in Equation 1 (AREA, POINT, LOCAL, and VISPLUME) be interpreted only in a relative sense to estimate source impacts. It would be inappropriate to use Equation 1 to predict concentrations at sites in cities other than the ones used in the data base (St. Louis, Birmingham, Portland and Kansas City). (Predictions were calculated for sites in Philadelphia, Pittsburgh and New England as a means of illustrating the validity of equation 1, but should not be interpreted as "$\mu g/m^3$" concentrations for control strategy development or other uses.)

An example of the calculation of the relative impacts of the variables LOCAL, AREA, POINT, and VISPLUME are discussed below. First, the variable values are calculated for each site. Then the coefficients (from Table 4) are multiplied times the variable values to give the calculated concentrations at each site which are associated with each variable. As an example, the calculation of the contribution from LOCAL sources at a site is given below.

$$LOCAL = \frac{\ln ADT_1}{\sqrt{HGT^2+DIS_1^2}} + \frac{\ln ADT_2}{\sqrt{HGT^2+DIS_2^2}}$$

where: $ADT_1 = 20$ = average daily traffic on Allegheny Avenue, vehicle/day

$DIS_1 = 20$ = distance from monitor to Allegheny Avenue, feet

$ADT_2 = 4900$ = average daily traffic on Delaware Avenue, vehicle/day

$DIS_2 = 65$ = distance from monitor to Delaware Avenue, feet

$HGT = 15$ = height of monitor, feet

LOCAL = .25 (calculated variable value)

Then the product of the coefficient and the LOCAL variable value is calculated. From Equation 1, the coefficient of LOCAL is 50.5. Calculating the product of the variable value, .25, and the coefficient, 50.5, gives a contribution due to LOCAL sources at the site of 12.6 $\mu g/m^3$.

The contributions of the LOCAL, POINT, AREA, and VISPLUME source categories at each site are similarly calculated as the first step in calculating relative concentrations. These predictions are then summed and the percentage contributions of each source category are calculated. When these percent contributions are compared, they represent the relative contributions of each source category to the ambient annual concentrations. The sum of the predicted concentrations may be compared with the actual observed concentration at a site. The difference is the amount of the observed which is unaccounted for by the LOCAL, POINT, AREA and VISPLUME terms. Table 6 gives an example of the predicted and relative impacts and amount unaccounted for at two sites in Philadelphia.

TABLE 6. EXAMPLE TABULATION OF THE PREDICTED AND RELATIVE IMPACTS OF POINT, AREA, LOCAL AND VISPLUME SOURCE CATEGORIES AT TWO SITES IN PHILADELPHIA

Site	Allegheny Avenue Predicted, $\mu g/m^3$	Allegheny Avenue Relative, %	Broad and Spruce Predicted, $\mu g/m^3$	Broad and Spruce Relative, %
LOCAL	12.4	29	28.5	56
VISPLUME	0	0	0	0
POINT	7.8	18	.44	1
AREA	22.1	53	21.9	43
Total Predicted	42.3		50.8	
Annual Average	107		116	
Unaccounted for by LOCAL, AREA POINT, VISPLUME Terms	65		65	

Control Strategy Applications

The method outlined above can provide much useful information for the development of control strategies in urban areas. The major limitation of the method is that it cannot be used to predict a "hot spot" concentration in an area where there are no monitors, such as can be done with a dispersion model unless the hot spot can be identified by some other means and a microinventory developed for that area. However, it provides much information about the relative impacts of source categories on measured annual concentrations.

Additional information on the sources which comprise the AREA and POINT concentrations can be inferred from the emissions inventories. If desired, the POINT, or AREA relative impacts could be apportioned among the major source categories which are found in the microinventory and were used in computing these variable values. The LOCAL and VISPLUME variables are suggestive of resuspended fugitive dust and vehicle exhaust emissions problems as well as monitor siting considerations.

LIMITATIONS OF THE METHOD

As with any technique for assessing data, there are certain limitations which must be recognized. These limitations include the range of variable values which can be used, as well as meteorological, geographic and other considerations.

Since this is a linear regression model, and since the model was "fit" to a limited range of variable values, it should only be used with variable values which are in the range of those in the 79 site data base. The minimum and maximum values for each of the variables are as follows:

	Minimum	Maximum
AREA	0	12,850
POINT	0	74,150
LOCAL	0	.95

There is some indication that the LOCAL relationship may result in somewhat high estimates for very low traffic levels (i.e., less than 1000 vehicles per day). This should be considered when interpreting the data. It may be justified to delete such roads from the analysis if, upon visual inspection, the roads appear to have very low levels of dust in the traffic lanes.

Another limitation concerns the minimum distance from point sources and the confounding effect of plume rise. Very few sites in the data base had a substantial volume of industrial emissions within one-half mile of the monitor. It can be shown from dispersion model calculations that high stacks and buoyant plumes may not have a significant effect on nearby monitors. Therefore it is suggested that no point sources closer than one-half mile be included in the POINT estimate. Analysis should not be attempted for sites which have a substantial number of stack emission points within one-half mile.

Some discretion must be used in applying this method to highly abnormal situations such as very dry climates, areas with excessive windblown dust or areas with very poor dispersion climatology. City-specific models may ameliorate some of these problems. Also, the method purposely limits the geographic area of consideration to one mile for area sources and five miles for point sources. Experience has shown that, while much of the particulate burden does come from outside of this area, most of this comes from outside of the urban area and not from, say a five-to-ten mile distance.[1,2]

As with any technique using emissions data, the accuracy of the inventory is very important. The microinventory procedure assures that sources within the prescribed limits are at least considered. However, it does not ensure the accuracy of these emission estimates. Faulty emission factors, seasonal variations in emission rates and process fugitive emissions are but a few of the factors that can contribute to an inaccurate emissions inventory.

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APPENDIX A

RAILROAD YARDS

Most of the emissions in train yards appear to be from wind erosion rather than from train movement. Therefore, an adaptation of the U.S. Department of Agriculture's wind erosion equation was used as the basis for deriving emission factors for railroad yards. The modified equation estimates annual suspended particulate emissions due to wind erosion from exposed soil surfaces:[6]

$$E = a\ I\ K\ C\ L'\ V' \qquad \text{(eq.1)}$$

where E = emission factor, ton/acre/yr

a = portion of total wind erosion losses that would be measured as suspended particulate, estimated to be 0.025

I = soil erodibility, ton/acre/yr

K = surface roughness factor

C = climatic factor

L' = unsheltered field width factor

V' = vegetative cover factor

In this equation, K, C, L', and V' are all dimensionless. An average erodiblity (I) of 56 ton/acre/yr was assumed to be applicable for the soil in the railroad yards. The area around railroad yards generally has a fairly smooth surface which is equivalent to a K value of 1.0. The climatic factor for the Kansas City area is 0.10. An average width of 1000 ft was assumed for railroad yards, since this is not a critical variable in the equation. The L' value equivalent to L = 1000 ft was determined from a nomograph in which soil type is also a variable--0.64. There is no vegetation in rail yards so V = 0 and V' = 1.0. Also, these areas are generally treated with oil or chemicals to reduce

dust and weed problems. Therefore, the emissions have been estimated with the above values and the following assumptions:

- no vegetation
- sandy soil (I = 56)
- half the area is stabilized, with an emission rate of 20 percent of the unstabilized area
- train traffic increases the wind erosion emissions by 20 percent

Therefore, the resulting emission factor is:

$$E = (0.025)(56)(1.0)(0.1)(0.85)(1.0)\left(\frac{1 + 0.2}{2}\right)(1.2)$$

$$= 0.1 \text{ ton/acre/yr}$$

REENTRAINED DUST FROM PAVED STREETS

The most recent emission factors for estimating emissions from paved roads were obtained from a draft of AP-42. The recommended emission factors are 5.0 gm/VMT for clean streets. These factors include an exhaust emission factor and are not corrected for days with rain.

Based on regional estimates for the percentage of heavy duty gasoline and diesel trucks, an exhaust emission factor of 0.6 gm/VMT was calculated from published emission factor data.[7] This factor was subtracted from the paved road emission factors and the resulting values were corrected for rainfall.

Rainfall data available for 1974 indicate that there were 86 days with at least 0.01 inch of rain. Based on this information, the reentrained dust emission factors were

reduced by approximately 24 percent. The corrected emission factors are: 3.4 gm/VMT for clean streets and 14.8 gm/VMT for commercial streets.

UNPAVED ROADS

Many different groups have investigated emissions from unpaved roads. All the studies show emission rates usually in the range of one to 20 lb/VMT, and show that the rate is highly dependent on vehicle speed. After reviewing these studies, EPA selected the following emission factor for publication in AP-42:[7]

$$E = (0.6)(0.81)(s)(S/30)\left(\frac{365 - w}{365}\right) \quad \text{(eq.2)}$$

where E = emission factor, lb/VMT

0.6 = fraction of total particulate less than 30 u diameter

s = percent silt of road surface material

S = average vehicle speed, mph

w = mean annual number of days with 0.01 inch or more of rainfall

The percent silt on gravel road surfaces is about 12 percent based on data presented in the EPA publication, Development of Emission Factors for Fugitive Dust Sources.[6] For graded and drained road surfaces, no aggregate material is applied to the roadbed so it is composed of compacted native soil. The fine material originally on the surface is probably rapidly removed by turbulence from passing vehicles or by wind and water erosion forces. The remaining stable surface is composed of sand- and pebble-sized particles, with dust being generated primarily by the continuing mechanical breakdown of these particles as a result of traffic.

It is assumed that the percent of silt-sized particles on a seasoned dirt road surface is approximately the same as that for gravel, or 12 percent. The number of days with 0.01 inch or more of rainfall is 86. Assuming a vehicle speed of 20 mph, the average emission factor is 3.0 lb/VMT.

CLEARED OR EXPOSED AREAS

The modified wind erosion equation described earlier was used for estimating emissions from cleared or exposed areas. An average erodibility (I) of 38 ton/acre/yr was assumed for the soil types common to this area. The cleared areas are generally left with a fairly smooth surface, which is equivalent to a K value of 1.0. The climatic factor for the Kansas City area is 0.10. An average field width of 1000 ft was assumed for all the cleared areas, since this is not a critical variable in the equation. The L' value equivalent to L = 100 ft was determined from a nomograph in which soil type is also a variable--0.64. There is no vegetation on cleared areas, so V = 0 and V' = 1.0.

Based on these input data, the average emission rate from cleared areas would be 0.06 ton/acre/yr.

CONSTRUCTION

The emission factor presented in AP-42 of 1.2 ton/acre/mo was corrected for the climatic conditions in Kansas City by use of the equation:[7]

$$E = \frac{1.2}{(PE/50)^2} \qquad \text{(eq.3)}$$

where PE = 95 for Kansas City

$$E = 0.33 \text{ ton/acre/mo}$$

This value is appropriate for residential and commercial construction with excavation and regrading, and includes the effect on emission reduction of moderate watering of the site.

AGRICULTURE

Total emissions from agriculture are calculated from the sum of tilling and wind erosion emissions. The factor for tilling from AP-42 is:[7]

$$E = (0.8)(1.4)s/(PE/50)^2 \qquad \text{(eq.4)}$$

where E = emission factor, lb/acre/run

0.8 = fraction of total particulate less than 30 u diameter

s = percent silt in surface soil

PE = precipitation-evaporation index

An average of three tilling operations per year is assumed, and a silt content of 40 percent. Therefore, total tilling losses are 37.2 lb/acre.

The modified wind erosion equation described earlier is recommended for determining the wind erosion component of agricultural emissions. All variables in the equation except C are dependent on either the soil type or crop grown on each field. However, this component is lower in magnitude than tilling losses in the Kansas City area, so the following average values were assumed:

$I = 47$

$K = 0.6$

$C = 0.1$

$L = 2000$ ft, $L' = 0.73$

$V = 500$ lb/acre, $V' = 0.14$

$E = 0.007$

Therefore, the combined agricultural losses are 0.026 ton/acre/yr.

AGGREGATE STORAGE AREAS

The emission factor for this source category was based on sampling performed in the Kansas City and Cincinnati areas. The emission factor (E) is:[6]

$$E = 13.2 \text{ lb/acre/day}$$

Assuming activity for six days a week, the annual emission factor is:

$$E = 2.1 \text{ ton/acre/yr}$$

UNPAVED PARKING LOTS

If the average number of vehicles using a parking lot daily and the average distance of travel in the lot can be estimated, these data can be converted to VMT/yr and then multiplied by the emission factor for unpaved roads to determine unpaved parking lot emissions. With an average speed of 10 mph in the parking lots, the emission factor is 1.5 lb/VMT. Usage of most lots for only five days per week was assumed in calculating annual VMT.

UNPAVED STORAGE AREAS

No factor was found for this source category. By comparison with other source categories, it was estimated that emissions per acre from this source were greater than for a cleared area (0.06 ton/acre/yr) or railroad yards (0.1), but not nearly as high as aggregate storage (2.1) or construction (4.0). A value of 0.2 ton/acre/yr was used for this minor source category.

GRAIN ELEVATORS

A value of 1.80 ton/silo/yr was developed from file data for a previous PEDCo study of particulate air quality in rural Kansas and Nebraska.[1] This same value was applied here for sources for which NEDS data were not available.

INCINERATORS

The emission factor for multiple chamber industrial/commercial incinerators from AP-42 was used in this inventory.[7] That value is 7.0 lb/ton of refuse incinerated.

Emission Factors and Formulas Used to Calculate
Fugitive Dust Emissions in Microinventory

Source category [a]	Emission factor	Units
Railroad yards	0.1	ton/acre/yr
Reentrained dust		
paved streets	3.4	gm/VMT[b]
exhaust	0.6	gm/VMT
Unpaved roads	3.0	lb/VMT
Cleared or exposed areas	0.06	ton/acre/yr
Construction	0.33	ton/acre/mo
Agriculture	0.03	ton/acre/yr
Aggregate storage	2.1	ton/acre/yr
Unpaved parking lots	1.5	lb/VMT
Unpaved storage areas	0.2	ton/acre/yr
Grain elevators	1.8	ton/silo/yr
Incinerators	7.0	lb/ton of refuse

[a] Other potential sources of fugitive dust which were not inventoried include:

Mining
Quarrying
Materials Handling
Snow and Ice Control
Feed Lots
Fairgrounds, etc.

[b] The emission factor given in Supplement 8 of Reference 9 will be 5.6 gm/VMT. This was "adjusted" to account for days with precipitation since it was assumed that resuspended dust would be suppressed on those days. Also, this factor was modified to exclude auto and diesel exhaust emissions.

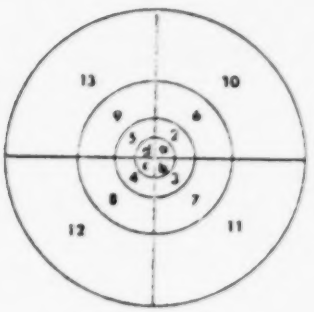
APPENDIX B

DESCRIPTION OF SITE

SAROAD code - 26 2380 005 H01

Location - 6402 East 37th,
Kansas City, Missouri

Monitor height - 35 ft, on roof of
fire station



Land use, by sector -

1a light industry
1b light residential
1c undeveloped
1d light residential

2 light industry
3 general industry
4 undeveloped
5 light residential

6 light industry
7 light industry
8 dense residential
9 dense residential

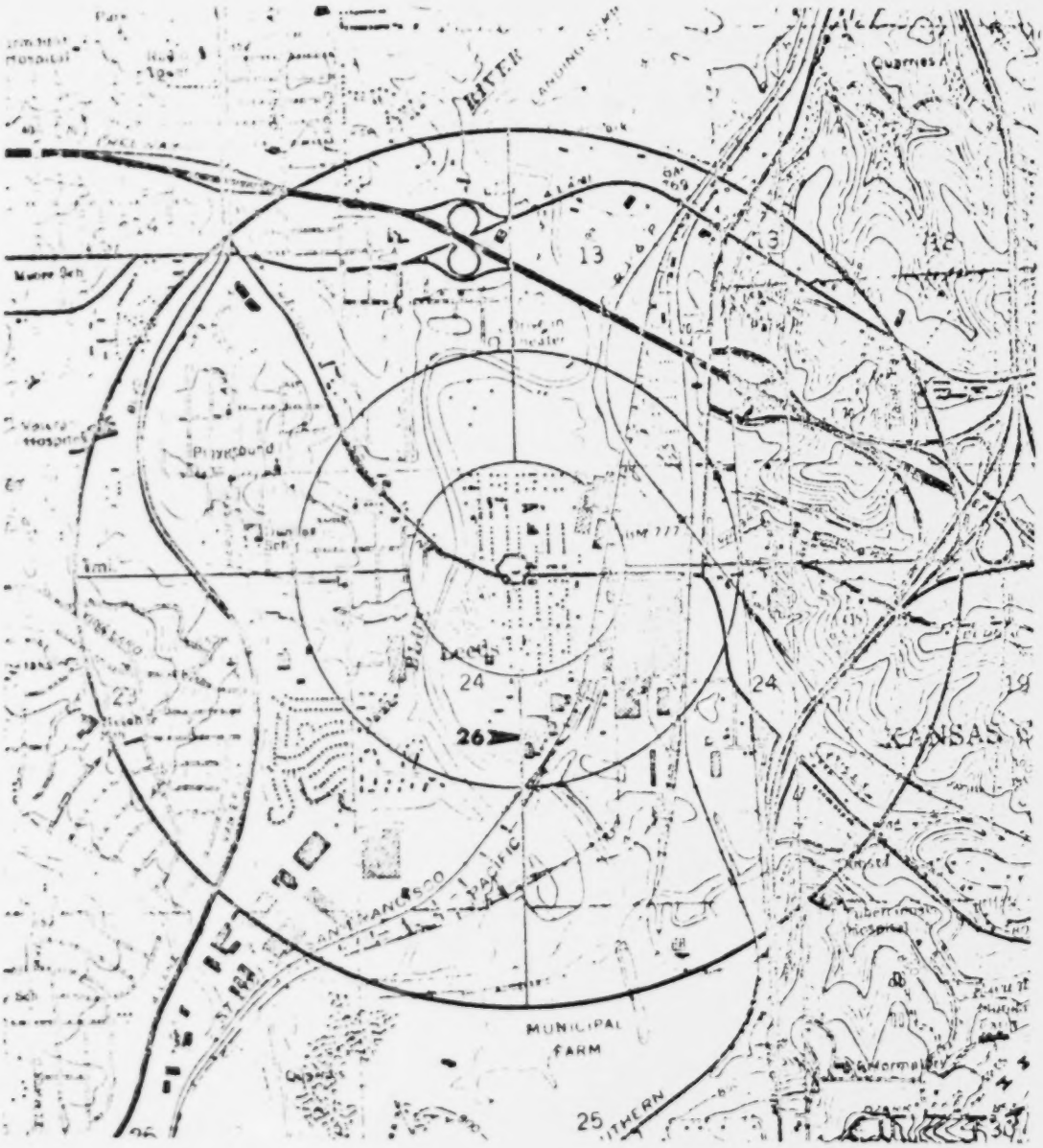
10 general industry
11 dense residential
12 dense residential
13 dense residential

Localized sources, within 200 ft of monitor -

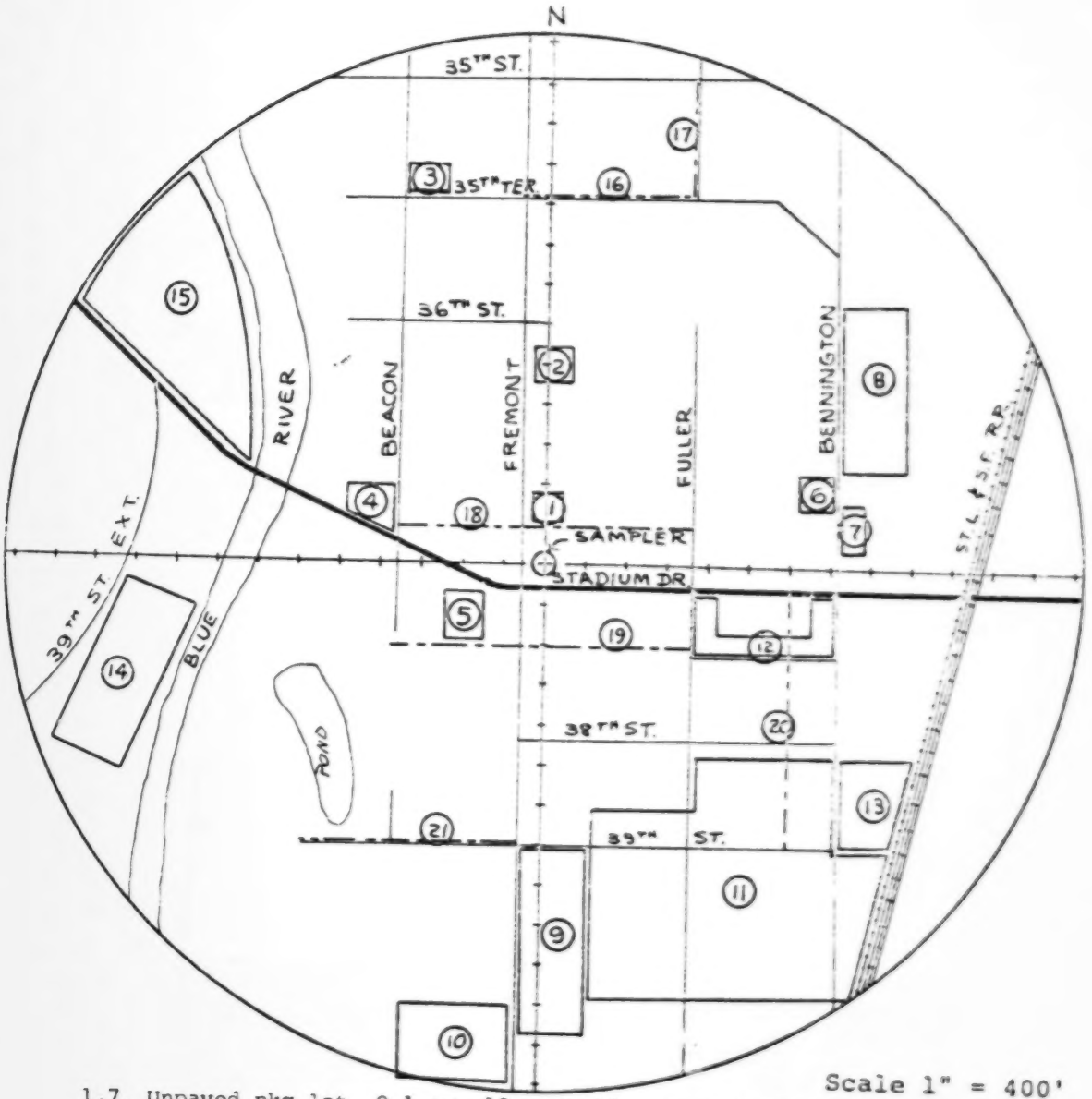
Source	Distance	Description
Stadium Drive	55 ft	7870 ADT, dirty, uncurbed
Unpaved parking lot	105 ft	0.1 acres, 10 cars
Unpaved alley	100 ft	5 cars
Fremont	60 ft	75 ADT, dirty, uncurbed

Air quality data -

Year	Annual geometric mean, ug/m^3	No. of samples
1977	85	-
1976	89	53
1975	86	54
1974	89	47
1973	101	51



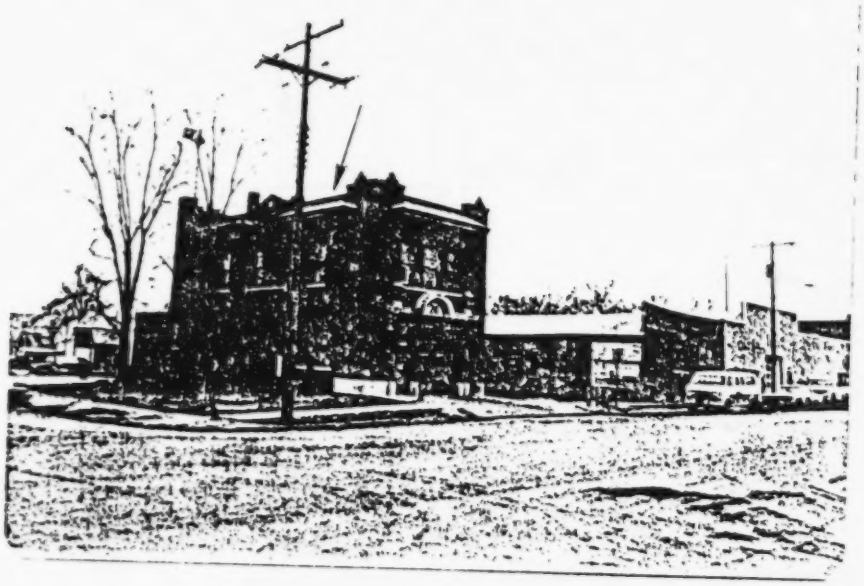
One mile radius around 6402 East 37th site.



Scale 1" = 400'

1,7. Unpaved pkg lot, 0.1 ac, 10 cars
2. Cleared area, 0.1 ac
3,6. Unpaved pkg lot, 0.1 ac, 5 cars
4. Unpaved storage area, 0.2 ac
5. Unpaved pkg lot, 0.3 ac, 25 cars
8. Unpaved pkg lot, 1.7 ac, 35 trucks
9. Unpaved pkg lot, 1.5 ac, 150 cars
10. Unpaved storage area, 2.0 ac
11. Unpaved storage area, 8.1 ac
12. Unpaved pkg lot, 0.8 ac, 20 cars
13. Unpaved pkg lot, 0.7 ac, 50 cars
14. Unpaved storage area, 3.4 ac
15. Unpaved storage area, 2.3 ac
16. Unpaved road, 400 ft, 5 cars
17. Unpaved road, 300 ft, 10 cars
18,19. Unpaved alley, 750 ft, 5 cars
20. Unpaved road, 675 ft, 5 cars
21. Unpaved road, 600 ft, 5 cars

One-quarter mile radius around 6402 East 37th site.



Viewed to the northeast.

Viewed to the northwest.

Sampler at 6402 East 37th.

POINT SOURCE SUMMARY

Site: 6402 East 37th

Plant number	Emission level, t/yr	Distance from site, mi	Compass direction, °
26	48	.39	180
25	893	1.7	35
24	98	2.4	25
23	43	2.7	20
22	1,233	3.5	10
16	249	4.3	5
15	41	4.4	0
13	341	4.7	350
14	327	4.8	0
9	46	5.1	330

AREA SOURCE SUMMARY

Site: 6402 East 37th

Source category	Activity rate	Emissions by sector, ton/yr									
		1	2	3	4	5	6	7	8	9	Total
COMBUSTION:											
Residential fuel	9491 pop	0.2	0.1	0.1	0.1	0.1	0.5	0.5	0.5	0.5	2.6
Comm/Ind fuel	8081 emp	0.5	0.4	0.4	0.4	0.4	1.5	1.5	1.5	1.5	8.1
Incinerators											
Rail/Air											
Auto exhaust	97.4×10^6 VMT	1.9	0.6	0.6	0.2	0.6	27.0	16.7	3.2	13.5	64.3
INDUS PROCESSES:											
Ind processes	4 sources	1		10					1.6	1.0	13.6
FUGITIVE DUST:											
Railroad yards	78 ac	0.4	2.0	1.2			3.0	0.5	0.7		7.8
paved streets	94.5×10^6 VMT	10.6	3.6	3.6	1.4	3.6	152.3	95.6	14.1	70.8	355.6
Unpaved roads	2.7×10^4 VMT	1.2									1.2
Cleared areas	0.1 ac	neg									
Construction											
Agriculture											
Storage areas	16 ac	3.2									3.2
Unpaved pkg lots	25.4 ac	4.8					12.0		7.4		24.2

Recap	Emissions by sector, t/yr			
	1	2-5	6-9	Total
COMBUSTION	2.6	4.0	68.4	75.0
IND PROCESSES	1.0	10.0	2.6	13.6
FUGITIVE DUST	21.8	15.4	404.2	441.4
Total	25.4	29.4	475.2	530.0

APPENDIX C

OTHER APPLICATIONS OF MICROINVENTORIES

Two uses of the microinventory method have been suggested, which do not require use of the empirical method. These are intersite comparisons and dispersion modeling.

Intersite Comparison of Inventories--The inventories for sites within a specific city can be compared to one another to indicate the differences in the nature of the sources near the monitors. Such a tabulation is made for two sites in Kansas City in Table C-1. This table summarizes the emissions around a site which is dominated by point sources (101 Lou Holland) and around a site dominated by fugitive dust sources (1517 Locust). Since both sites report roughly comparable high annual averages, it is reasonable to assume that the Lou Holland concentrations are due primarily to the point sources and the Locust Street site is primarily influenced by fugitive dust sources. Obviously, such a clear pattern is not always so apparent, and a detailed analysis of the data at many such sites may be necessary before making conclusive inferences about the magnitude of the impact of these different types of sources. This could be done using a dispersion model or through the use of a multiple linear regression to explain effects of the variables used.

In another example, shown in Table C-2, both sites have relatively small industrial emissions. However, the area source inventory indicates great differences in the fugitive dust emissions within the nearest 1/4 mile. In this example, the Missouri Avenue site is dominated by localized sources, whereas the Ann Avenue site is not so dominated. This difference in nearby

TABLE C-1. Comparison of Point and Area Source Inventories at Sites in Kansas City with Comparable Air Quality Concentrations

	EMISSIONS AND SOURCES NEAR MONITORING SITES [a]	
	101 Lou Holland Drive	1517 Locust Street
AREA SOURCES		
1/4 mile	1.1	87.1
1/4 to 1/2 mile	22.5	196.1
1/2 to 1 mile	353.2	769.7
POINT SOURCES		
1 mile	853	28
1-2 miles	2266	805
2-3 miles	4061	1356
AVERAGE CONCENTRATION		
1975-76 Average Annual Geometric Mean, $\mu g/m^3$	93	102

a. Emissions in tons per year

TABLE C-2. Comparison of Local Fugitive Dust Source Contributions and Average TSP Concentrations at Two Sites in Kansas City with Comparable Point and Area Source Emissions

	EMISSIONS AND SOURCES WITHIN 1/4 MILE, TPY *	
	405 Missouri Avenue	619 Ann Avenue
AREA SOURCES		
Combustion	18.5	5.6
Industrial	0.0	0.0
Fugitive Dust **	74.4	22.4
LOCAL FUGITIVE DUST SOURCES **		
Distance, ft.	65	130
Traffic, veh/day	46,220	800
AVERAGE CONCENTRATION ***	118	69

* Total area source emissions within 1 mile were comparable for the two sites as were total point source emissions within 2 miles, tons per year

** Fugitive Dust includes dust resuspended by traffic

*** Average of annual geometric mean concentration in 1974 and 1975 at each site, $\mu g/m^3$

sources and emissions could explain much of the difference in air quality levels between the sites. As mentioned earlier, dispersion or regression models could be used to help quantify these effects.

Dispersion Modeling Using Improved Emission Inventory Data Base--As mentioned earlier, emission inventory input to dispersion models are generally conducted using grid sizes of 1 or 2 km square. The emissions from many source categories are "allocated" to these grids using population or other indicators. The studies cited earlier indicate the importance of nearby sources in explaining TSP concentrations and support the need for more accurate inventory methods and data in the vicinity of particulate monitors.

The microinventory technique directly addresses the problems associated with "allocation" procedures through the use of detailed site surveys and inventories based on site inspections. Also, the technique can easily be adapted to a Cartesian coordinate system (from polar coordinates), resulting in a small, detailed grid system for use in dispersion models.

It has been established that distance from source to receptor is an important consideration in explaining TSP concentrations. Thus, it follows that a smaller grid size would provide greater resolution of source-receptor relationships.

A rectangular microinventory grid, such as is depicted in Figure 2, is recommended for use in dispersion modeling. It closely corresponds to the polar gridding technique in Figure 1. Such a grid system should be incorporated into the grid system for the urban area being modeled to provide better source-receptor resolution in the immediate vicinity of the monitoring sites being used in model applications. In converting the polar inventory to

rectangular grids, a simple and consistant method would be to grid the area surrounding the site into .5 km square grids. The closest four grids would be assigned the same emission density as inventoried in sector 1. The surrounding ring of .5 km square grids would be assigned the same density as sectors 2 through 5. The outer grids would be divided into 1 km square grids and would be assigned the same density as sectors 6 through 9. Obviously, if one were performing a microinventory specifically for dispersion model inventory improvement, it should be made using the grid system in Figure 2.

APPENDIX D

Variables Screened for Inclusion in Regression

The following variables were screened by computing simple correlations with Average Annual Geometric Mean Concentration computed for up to five year's data.

1. Height of monitor (HGT)

2. Distance of monitor to each of nearest two roads (DIS1, DIS2)

3. Average daily traffic on each of nearest two roads (ADT1, ADT2)

4. The following terms combining traffic, height and distance to nearest roads.

   a) $\frac{\ln ADT1}{\sqrt{DIS1^2+HGT^2}} + \frac{\ln ADT2}{\sqrt{DIS2^2+HGT^2}}$

   b) $\frac{\sqrt{ADT1}}{\sqrt{DIS1^2+HGT^2}} + \frac{\sqrt{ADT2}}{\sqrt{DIS2^2+HGT^2}}$

   c) $\frac{ADT1}{\sqrt{DIS1^2+HGT^2}} + \frac{ADT2}{\sqrt{DIS2^2+HGT^2}}$

5. The following terms combining point source emissions (PS), distance to each point source (DPS), stack height (STHT) and wind direction weighting factor (WWF)

   a) $\frac{PS\ (wwf)}{DPS}$

   b) $\frac{PS\ (wwf)}{DPS^2}$

   c) $\frac{PS\ (wwf)}{DPS}$ $(STHT \leq 60\ ft)$

   d) $\frac{PS\ (wwf)}{DPS}$ $(STHT > 60\ ft)$

   e) $\frac{PS\ (wwf)}{DPS\ (\ln(STHT))}$

   f) $\frac{PS\ (wwf)}{DPS^2\ (\ln(STHT))}$

6. The following terms combining the area source emissions for combustion and small industrial sources (ACI01 thru ACI09); paved roads (APR01 thru APR09); and other fugitive sources (AOF01 thru AOF09) where 01 thru 09 are sector designations.

a) $ACI = \sum_{n=01}^{09} ACIn\ (wwf)$

b) $APR = \sum_{n=01}^{09} APRn\ (wwf)$

c) $ADF = \sum_{n=01}^{09} AOFn\ (vwf)$

d) $ATOT = ACI + APR + AOF$

e) $ATOT1 = ACI01 + APR01 + AOF01$

f) $ATOT25 = \sum_{n=02}^{05} ACIn + \sum_{n=02}^{05} APRn + \sum_{n=02}^{05} ADFn$

g) $ATOT69 = \sum_{n=06}^{09} ACIn + \sum_{n=06}^{09} APRn + \sum_{n=06}^{09} ADFn$

h) $ATOT1H = ATOT1\ (\frac{25}{HGT})$

i) $ATOT25H = ATOT25\ (\frac{25}{HGT})$

j) $ATOT69H = ATOT69\ (\frac{25}{HGT})$

k) $ATOTD = \frac{ATOT1}{D1} + \frac{ATOT25}{D25} + \frac{ATOT69}{D69}$

where D1, D25 and D69 are the distances to the area weighted centers of Sectors 1, Sectors 2-5 and Sectors 6-9

l) $ATOTDS = \frac{ATOT1}{D1^2} + \frac{ATOT25}{D25^2} + \frac{ATOT69}{D69^2}$

7. Presence of visible plume of resuspended dust after passage of car on a road, VISPLUME.